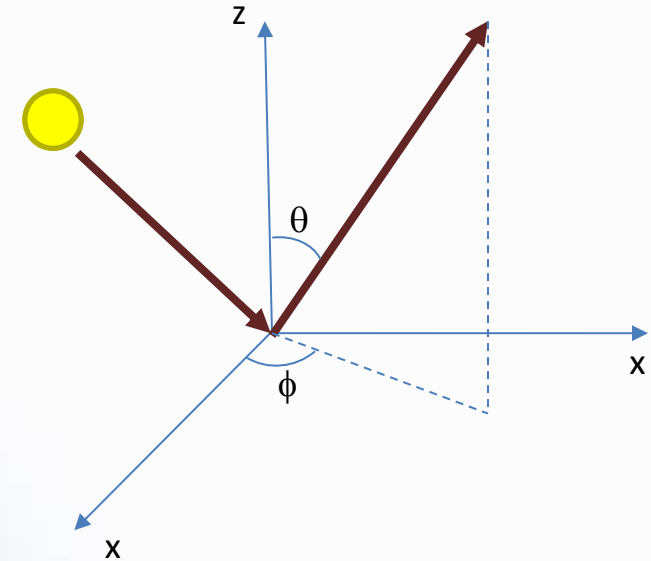# Algodones Dunes – A Surrogate for Libya 4
Establishing the BRDF of Calibration Sites:

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Image Processing Lab

SDSU Image Processing (IP) lab Absolute Calibrations

A lab task: Establish/maintain the in-band on-orbit radiometric calibration of various satellite based sensors: **Vicarious Calibration**

- Use ground based (variant on 'the reflectance method')
- Pseudo Invariant Calibration Site method (PICS)

Base techniques are well established for both; however, as user's improve their techniques, even greater increases in radiometric accuracy and precision with more immediate updating (sub-seasonal rather than yearly) is desirable.

PICS has been optimized to produce high precision and accuracy for nadir views of a select set of sites (primarily high reflectance desert sites). A goal is to extend the technique to produce the same level of accuracy to off-nadir views and to increase the frequency of calibrations and the reflectance range by establishing a more robust set of sites.

Focus on PICS angular reflectance
BRDF: Bidirectional Reflectance Distribution Function

Concept: For uniform solar illumination (E_{sun}) the absolute reflectance of the surface generally has an angular distribution.

Radiance as measured by the sensor (shown as an eye) depends on a number of geometric factors as well as the absolute characteristics of the surface causing the reflection.

We wish to understand and mathematically characterize this relation for our 'calibration surfaces' (that is, our calibration sites) to maximize the accuracy of PICS based calibrations.

Backward Scattering   Forward Scattering
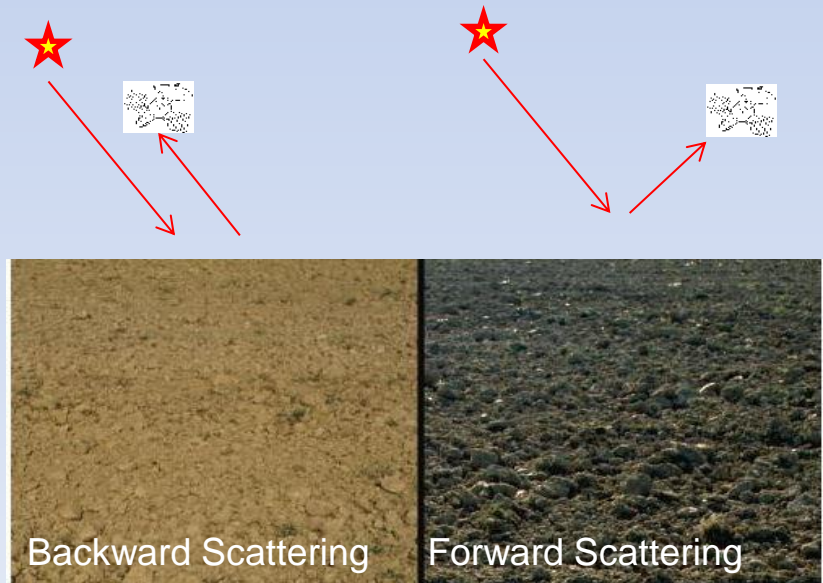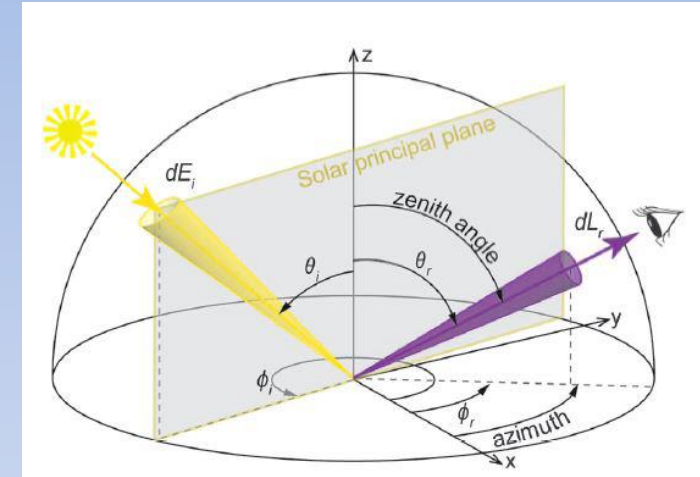
Use BRDF as a basis function

- $f_{BRDF}(\theta_i, \emptyset_i, \theta_r, \emptyset_r) = \dfrac{L_{surface}}{E_{surface}}$ units are [sr^{-1}]

- Simply the ratio of the outgoing radiance of a surface element divided by the radiance incident upon that surface.

  - 'Bidirectional': *Appearance does not change when source and viewing directions are interchanged.*

  - 'Lambertian' surface: *Surface appears equally bright in all directions; $L_{surface}$=constant wrt to view angles (life would be easy IF we had Lambertian surfaces)*

  - *Typically we write (for sunlit remote sensing applications)*

    $$L_{surface} = \frac{E_{sun}}{\pi} \rho_{surface} \cos\theta_{sun} = \frac{E_{sun}}{\pi} \rho_{surface} \vec{n} \cdot \vec{s}$$

    $\vec{n}$ is surface normal vector
    $\vec{s}$ is ground point to sun

  - If we have a non-lambertian surface, we need to basically characterize that $\rho_{surface}$ in terms of both the solar and the satellite angles (theta and phi).
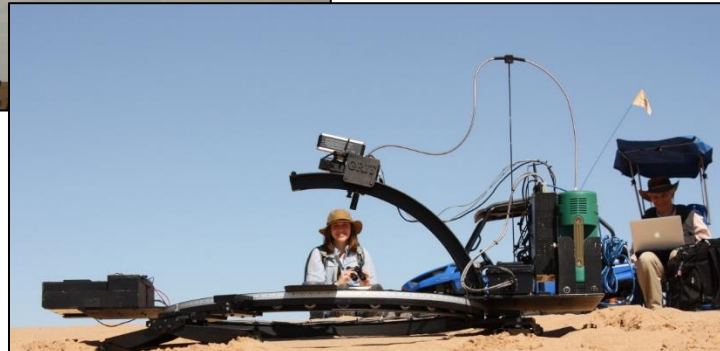
In 2015 a joint campaign measured BRDF using a number of techniques at Algodones Dunes
March 8-12

SDSU, U of Az, GSFC, U of Lethbridge, RIT, INPE
- Ground radiometric measurement:
- Spatial, angular view, various slope, etc
- Aircraft (G-LiHT)
- Samples taken for later lab measurement

SDSU Initial results: Mahesh Shrestha

Two approaches to analysis:

Analysis of the Field ASD spectro-radiometer reflectance data: Measured reflectance versus view angle for the principal plane and perpendicular to the principal plane. Categorized for surface location and surface slope angle.
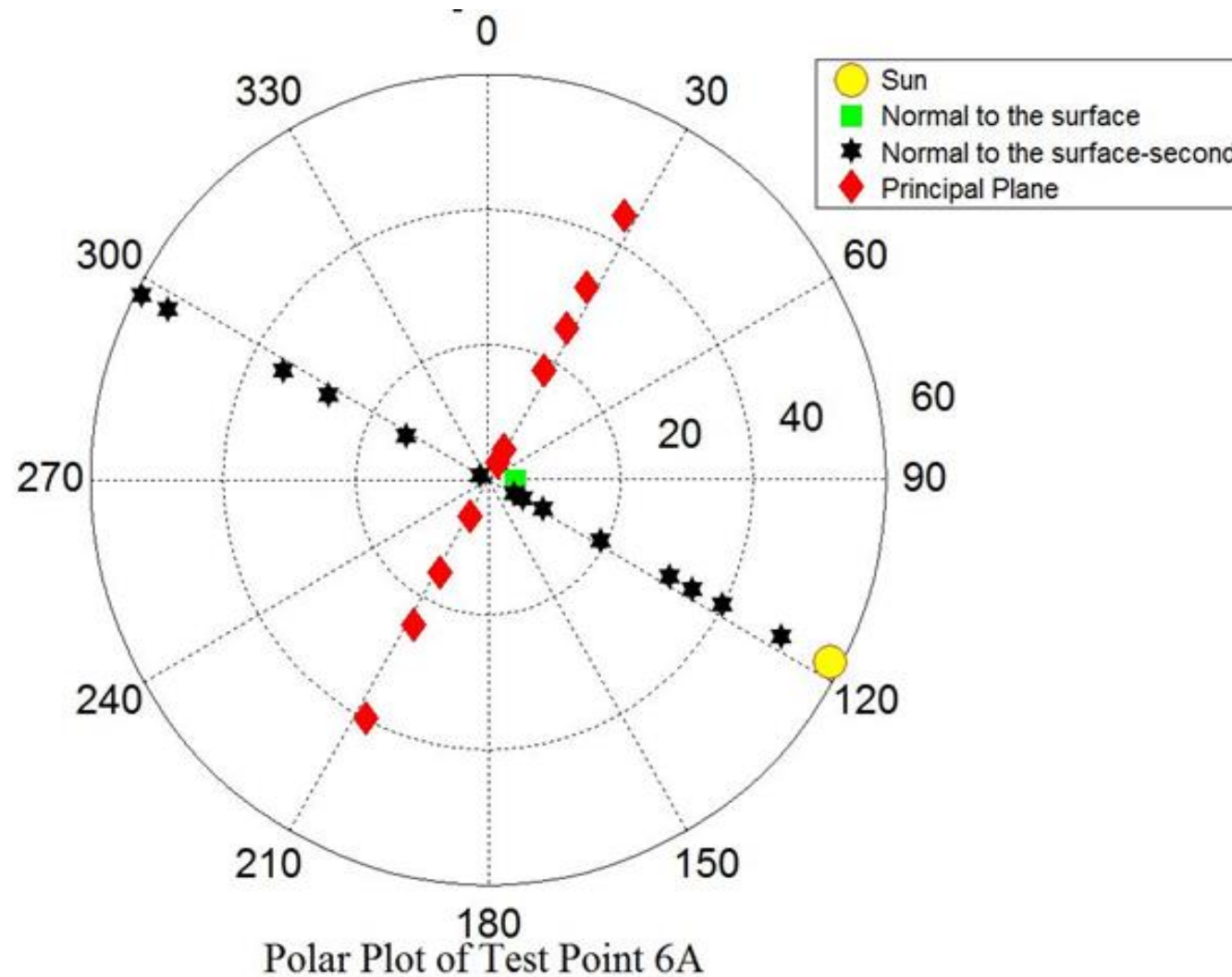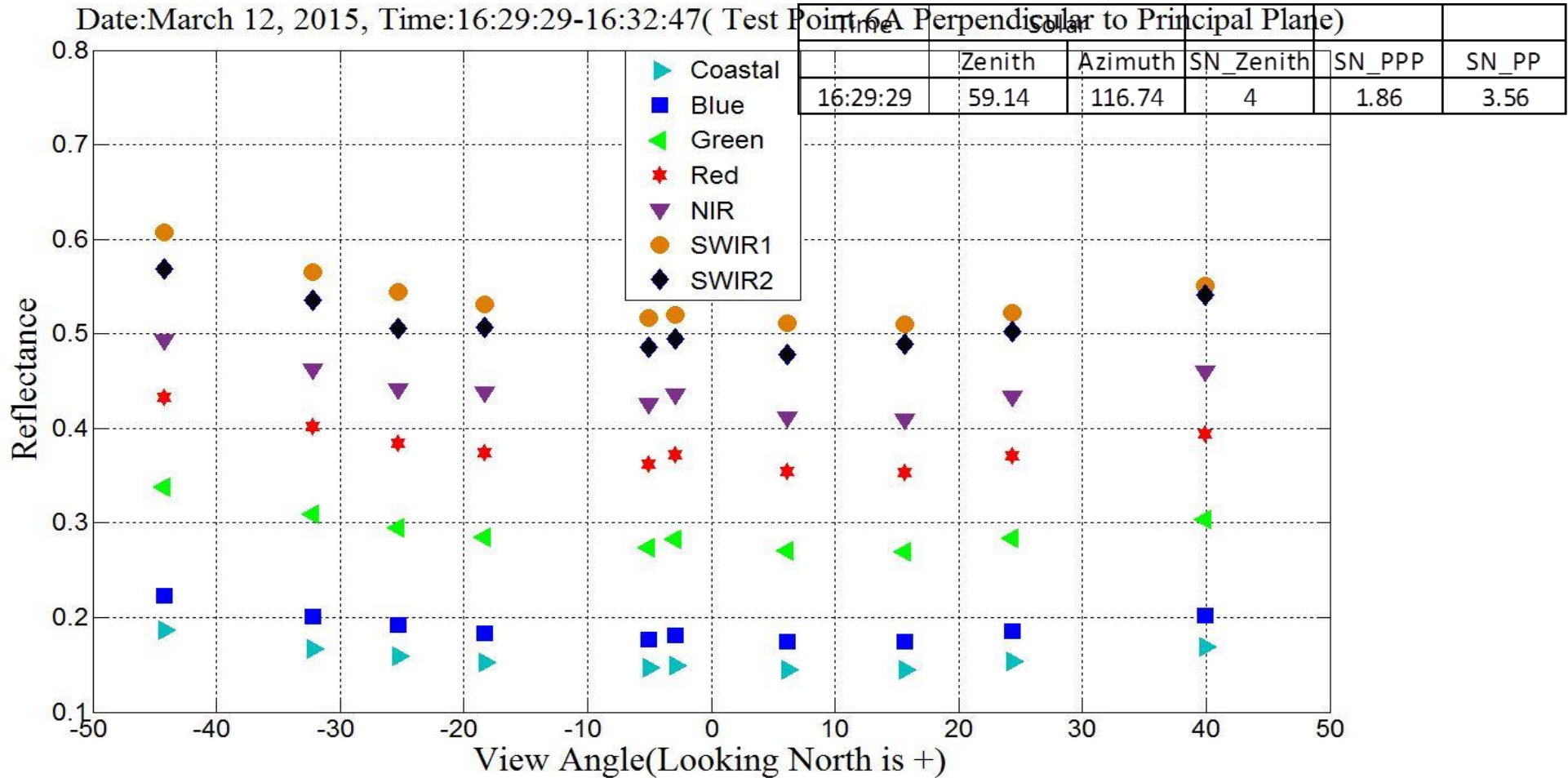
Laboratory Measurement:

Again measured sand reflectance. Here measurements concentrated on perpendicular to the principal plane values.

# Typical Measurement set: Polar Plot of Test Point 6A

Polar Plot of Test Point 6A

BRDF Of Sand: Algodones Dunes (6A Perpendicular to the Principal Plane)

Date:March 12, 2015, Time:16:29:29-16:32:47(Test Point 6A Perpendicular to Principal Plane)

Time	Solar		SN_Zenith	SN_PPP	SN_PP
	Zenith	Azimuth			
16:29:29	59.14	116.74	4	1.86	3.56

Legend: Coastal, Blue, Green, Red, NIR, SWIR1, SWIR2

Y-axis: Reflectance
X-axis: View Angle(Looking North is +)

➢ BRDF as measured by ASD banded to OLI RSRs for point 6A Perpendicular to Principal Plane and in the Principal Plane
➢ All bands have roughly the same angle dependencies

BRDF Of Sand: Algodones Dunes (6A Parallel to the Principal Plane)

Time:16:35:04-16:38:45(Test Point 6A Parallel to Principal Plane)
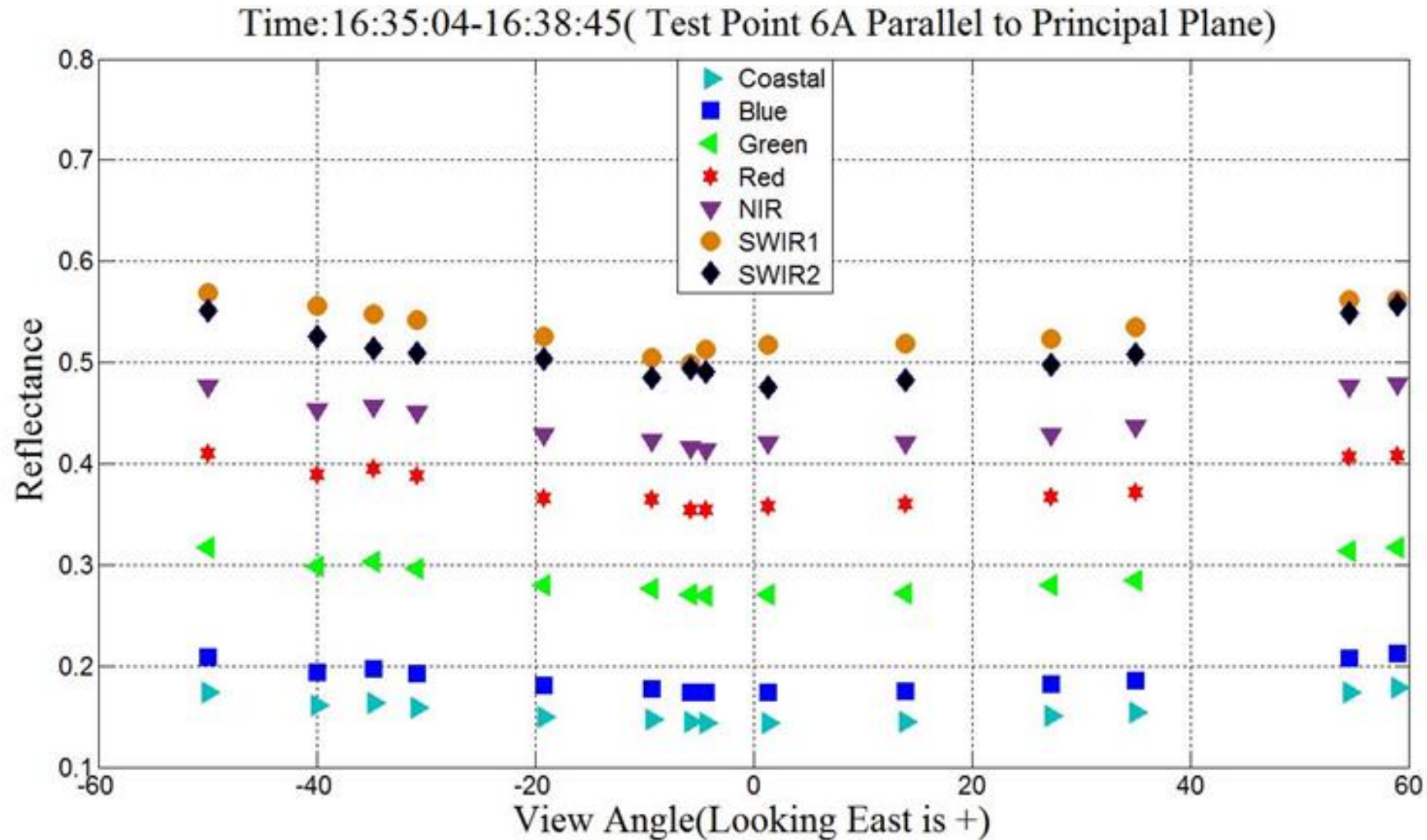
➤ Similar to PPP, all bands have roughly the same angle dependencies

Normalized and expanded BRDF of sand: Algodones Dunes (Test Point 6A Perpendicular to Principal Plane)



Normalised BRDF of Sand,Time:16:29:29-16:32:47(Test Point 6A Perpendicular to Principal Plane)
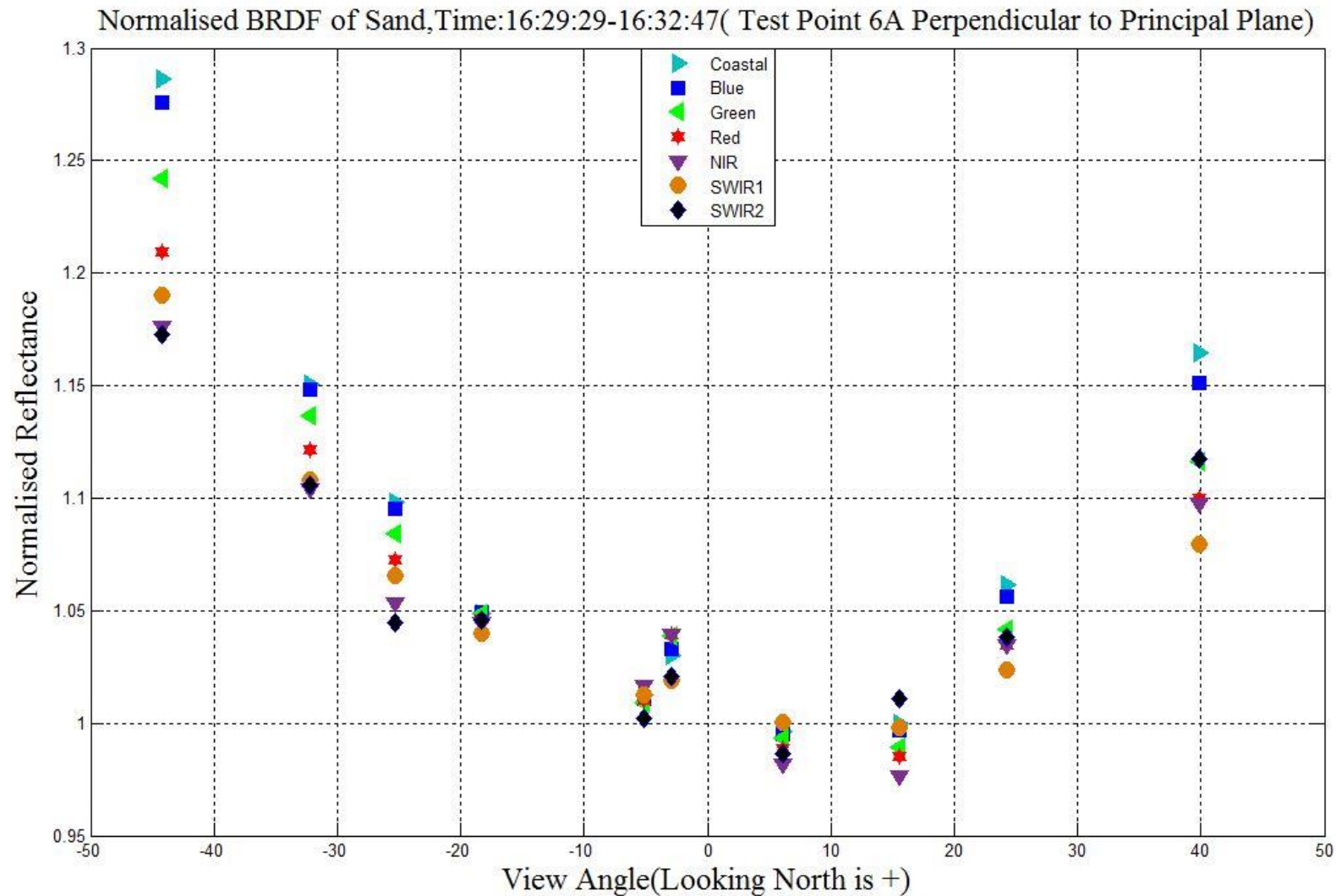
➤ Normalized data gives a better understanding across the wavelength.
➤ As view angles increases shorter wavelength deviates from longer wavelength.

Hyperspectral reflectance: Sample 6A (perpendicular to principal plane)

Comparision of Reflectance Spectrum with Different View Angle
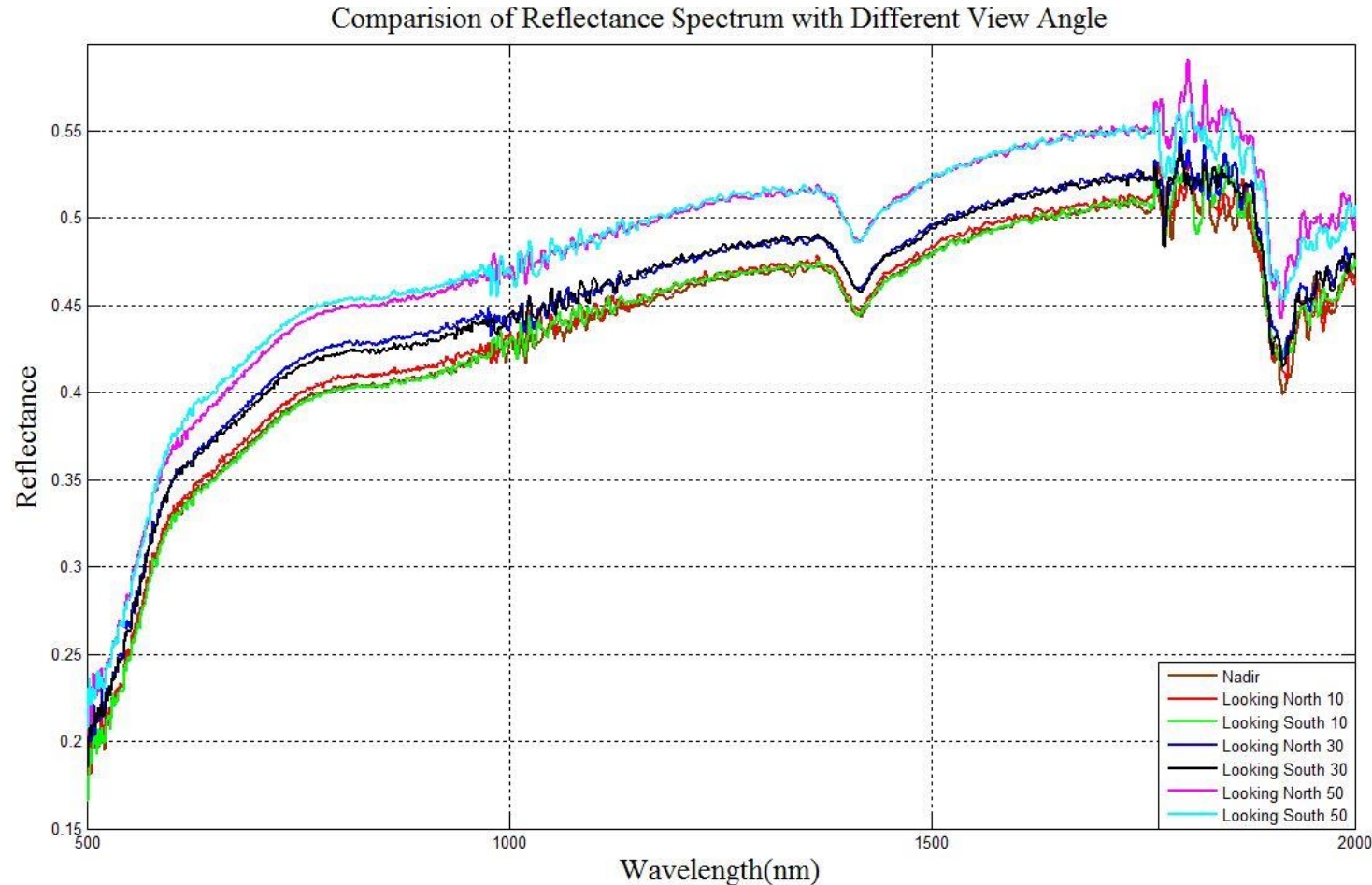
> ➢ In shorter wavelength, reflectance is slightly higher when we are looking from South
> ➢ In higher wavelength, signal is somewhat noisy
> ➢ Reflectance curve looks tight when we are looking from North and South (Perpendicular to Principal Plane)

BRDF of Sand from Lab Measurement (Test Point 1D)

BRDF of Sand from Lab measurement
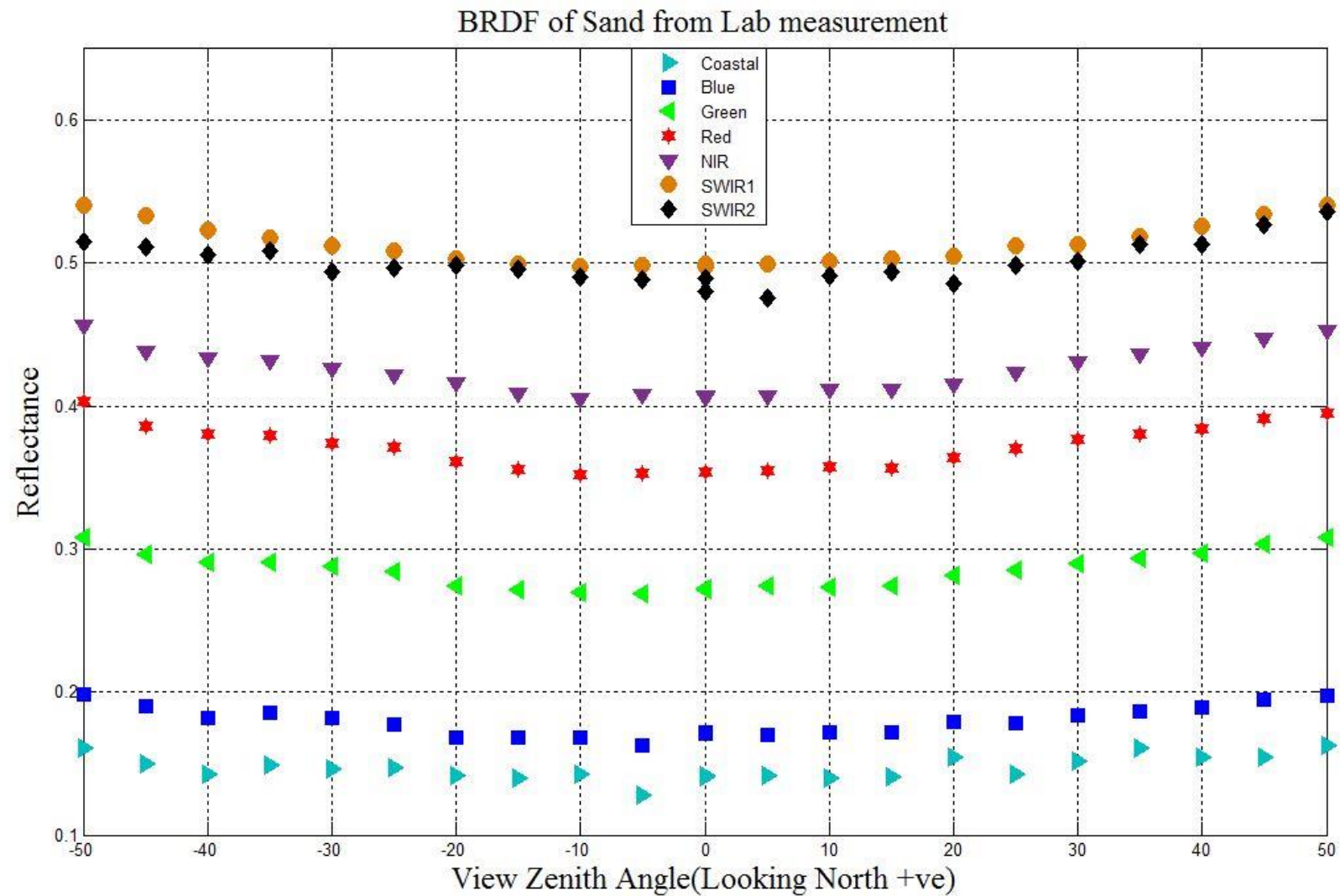
Laboratory BRDF measurement: (Perpendicular to Principal Plane: Sample 1D)

BRDF of Sand from Lab measurement(average of nine BRDF run)
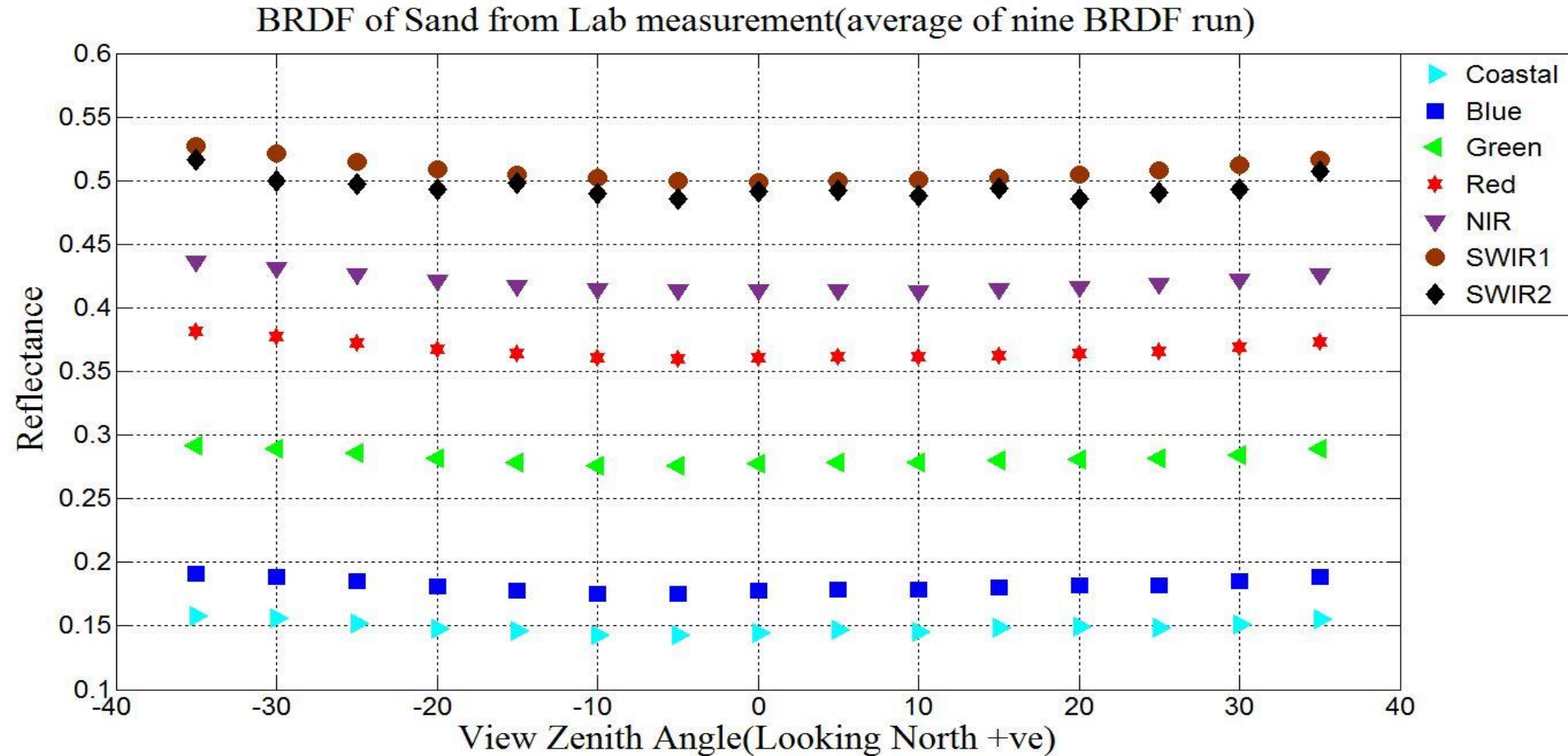
➢BRDF measured by ASD is banded to OLI RSRs
➢Reflectance increases with viewing angle in all bands
➢Field measurements BRDF curves are symmetric
➢Due to noise in signal, BRDF of Coastal and SWIR2 bands isn't as symmetric as other bands

Key questions:

The lab has developed the tools to measure BRDF both in the field and in the lab, along with relevant statistical tools to determine significance of the acquired results; now we can ask:

- Is BRDF behavior of sand similar for 'in the principal plane' and 'perpendicular to the principal plane'?

- Can laboratory measurement of the sand replicate the field behavior of the sand?

- What mathematical description best characterizes the angular reflectance behavior for Algodones dunes sand?

- Is this description only good for a single location (or location type) within the dunes area, or is it general?

Brief summary of answers:

- Is BRDF behavior of sand similar for 'in the principal plane' and 'perpendicular to the principal plane'?

  As could be seen in the previous plots, the overall behavior is the 'reflectance smile' and for the samples analyzed, the net behavior in the two planes is statistically the same.

- Can laboratory measurement of the sand replicate the field behavior of the sand?

  As could be seen in the previous plots, the net 'reflectance smile' for the field data and the lab data are the same (both observationally and statistically). The one difficulty in the lab data is getting good S/N in the NIR due to the low output of the lamps in this region.

Summary (continued)

- What mathematical description best characterizes the angular reflectance behavior for Algodones dunes sand?

  In short, it is a model where a linear term sets the base nadir reflectance and a quadratic term describes the angular behavior.

- Is this description only good for a single location (or location type) or is it general?

  This description, and quadratic coefficients, works for a wide range of sampled areas within the dunes, a final quantification is to determine if a single set of values can be determined.

Overarching Questions:

How do SDSU's results compare with other team member's results?

Informal discussion are indicating similar results; however, a formal comparison has not yet been made. It is time for a team meeting. As yet TBD.

Will these values be directly applicable to other desert sites?

The tools and techniques developed for this project will be extended to both subsets of Algodones Dunes sand and to 'other sand types'. The results here imply that the basic functionality is the same but it is being evaluated as to how much or if coefficients have to be adjusted for sand type?